Temporal Aspects in Conditioning the Galvanic Skin Response

By
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CHAPTER I

INTRODUCTION

Problem

The purpose of this experiment is to investigate the temporal gradient between a pure tone conditioned stimulus (CS) and mild shock unconditioned stimulus (UCS) and the extent of classical conditioning of the impedance change galvanic skin response (GSR) in human subjects (Ss) when partial reinforcement is used.

Studies which have investigated the temporal interval between the CS and the UCS in relation to the conditioning of phasic responses have indicated that: (a) backward conditioning, if present at all, is much less pronounced than forward conditioning (1, 2, 17, 20, 21, 22)*; (b) the CS-UCS interval for optimal conditioning lies between 0.2 and 1.0 seconds (secs.) (10, 17, 20, 21, 22); and (c) little, if any, conditioning occurs when the CS-UCS interval is equal to or greater than 2.5 secs. (10, 17, 20, 21). All time intervals, including those in quoted material, are measured from the onset of the CS to the onset

*Throughout the text, numbers in parenthesis refer to literature cited in the numbered Bibliography at the end of the study.

of the UCS. These intervals and stimulus durations will be expressed in units of seconds or decimal fractions thereof. Studies of autonomic responses have also indicated backward conditioning, if present, to be much less pronounced than forward conditioning. Other comparisons between phasic and autonomic responses have yielded inconsistencies. The results of some studies (11, 19), in which forward intervals equal to or in excess of 2.5 secs. were used in conditioning autonomic responses, have been similar to those in which phasic responses were conditioned. In other studies (3, 12, 14, 18), results have suggested that the optimal interval for autonomic conditioning may be somewhat greater than 0.5 sec. Hilgard (6) has stated that "the practice in conditioning salivation, galvanic skin response, and pupillary reactions has been to use somewhat longer intervals but the critical experiments on time interval have not been done" (6, p.527).

History

Conditioning of Whole-Body Responses, Molar Behavior. In an early study, Carr and Freeman (1) gave rats preliminary training in a maze so that, through reward training, they learned to turn around on seeing a closed door blocking their customary path to a foodbox goal, and to take the alternate path to the goal. Next, training trials were

given in which eight rats were presented an 0.8-sec. buzz as they were turning around, eight rats were presented the buzz just prior to the time they would normally see the block in the pathway, and nine rats were presented the buzz at the time they sighted the block. This experiment can be discussed in the language of conditioning. Thus the original stimulus for turning, the closed door, became the UCS; the buzz served as the CS. Test trials were given during training by presenting the CS before the closed door, the UCS, was sighted. The point in the path at which the CS was given was varied in order to prevent the formation of a position habit. The conclusions, based on relative percentages of conditioned response (CR), were that "associated terms function much more readily in a forward than backward direction. . .and successive presentation constitutes a much more favorable method. . .than does simultaneous presentation" (1, p.471).

A conditioning description can also be applied to an experiment by Yarborough (22) who repeated basically the same experiment as Carr and Freeman (1). In the preliminary training, his rats, which were run singly, were shocked for 0.5 sec. on 7 out of 10 runs. If they did not turn when shocked and take an alternate path to the foodbox, the foodbox door was closed. There were 20 trials per day until 90% of the last 100 trials were correct. Conditioning

trials were given in which a short buzzer CS preceded the shock UCS by 1.0, 2.0, 4.0, and 6.0 secs., or immediately followed it. Level of conditioning was determined by counting the number of trials necessary to obtain 90% correct responses on the last 100 trials. Very little backward conditioning was found. Other findings indicated "a disproportionate increase in difficulty when the interval is increased from 1.0 to 2.0 secs. There is practically no increase when the interval is increased from 2.0 to 4.0 secs. The 6.0-sec. interval is more difficult than the 4.0-sec., but the increase in difficulty is not so great as from the 1.0-sec. to the 2.0-sec. interval" (22, p.24).

Conditioning of Limited Motor Responses, Molecular Responses. In another experiment using rats as subjects, Coppock (2) conditioned them to make a lateral head flexion. Fourteen of the animals were trained with a blinking light CS of 1.0-sec. duration. The UCS was a 5.0-sec., 0.20-milliampere (ma) shock applied to the tail. The CS immediately preceded the UCS, or coincided with the last second of it. Twenty additional rats were trained under similar conditions, except that a clicking relay provided an auditory CS. It was found that more conditioning occurred when the CS preceded the onset of the UCS.

In conditioning the human knee jerk, Schlosberg

(15) used a bell CS and a blow to the knee UCS. There were 49 subjects. "When the interval between conditioned and unconditioned stimuli was varied between 0.20 and 0.44 seconds there was no significant difference in ease of conditioning; but when this interval was decreased below 0.11 seconds it was more difficult to form a conditioned reflex" (15, p.494).

H. M. Wolfle (20) conditioned the human finger withdrawal using a sound hammer CS and 1.75-sec. shock UCS. The strength of the shock was continually adjusted to cause withdrawal without its being excessively painful. Ninety students in an elementary psychology course were divided into nine subgroups according to the time interval between CS and UCS. There were 0.25-sec. steps from .50 sec. after shock went on to 1.50 secs. before shock went on. The auditory stimulus alone was presented on three irregularly placed trials out of 20. Amount of conditioning was expressed as per cent CR on non-reinforced trials. Results indicate that:

> ". . .Many subjects were never conditioned. . . . The 0.50-second interval [in which sound precedes shock]. . .was most effective for conditioning. . . . The interval of 0.25 seconds with sound first was next most effective. . . . The simultaneous relationship was inferior to those previously mentioned. . . . But instead of the curve dropping immediately to the zero line as soon as the simultaneous point was past, only a slight decrease was obtained. . . .

> With the 1.50-second interval with the conditioned stimulus first the mean was only 8%" (20, p.377).

In a follow-up study, Wolfle (21) used a solenoid click as the CS and an inductorium shock as the UCS in conditioning finger withdrawal. Seventy-two students in elementary psychology, six in a control group, were used as subjects.

> "On those intervals in which the unconditioned stimulus was presented first very few conditioned responses occurred. . . . The zero interval, or simultaneous relationship, produced very little conditioning. . . . Beginning with the 0.2-second interval in which the conditioning stimulus was first presented, there is a sharp rise in the curve. . . . Intervals longer than 0.6 seconds. . .resulted in no stable conditioning with any subjects, with many subjects, in no conditioning at all" (21, pp.96-98).

In her first experiment, Wolfle (20) revolved the disc which presented the paired stimuli once in 8.5 secs. Hence, "When the conditioned stimulus was presented 0.50 seconds before the unconditioned, it was also presented 8 seconds after" (20, p.375). At least once every 20 stimulations, the motor was temporarily turned off, thus allowing a longer interval. In the second experiment described above, Wolfle (21) paired stimulations which were given several pairs a minute--i.e., 12, 8, 15, 9, and 16 secs. apart.

Kappauf and Schlosberg (7) have investigated the possibility that these relatively short periods between

successive pairs of stimulation may have made Wolfle's (20, 21) longer forward intervals comparatively ineffective. Rats served as their subjects. The animals were strapped in place astride a block of wood. In the general part of the experiment, a loud buzz CS was presented 0.33, 0.66, 1, 2, 4, and 7 secs. before the onset of a half wave rectified shock UCS. The buzz and shock overlapped 0.33 sec. in one member of a training pair. For the other, shock could be prevented by a 1 mm leg flexion. In the first experimental group the relative effectiveness of the 0.33- and 0.66-sec. intervals were compared. They found that "better conditioning attends shorter intervals of delay" (7, p.34). There were differences from response to response. In the case of leg withdrawal, "the level of conditioning as indicated by this response was quite low. [For all leg movements] the increased incidence of these minor leg movements does not indicate greater effectiveness of the long period. . ." (7, p.34). For sharp inspirations, "the shorter intervals were most effective for conditioning, [but] when one considers all modifications of the rate and form of breathing, the gradient of effectiveness for the different delay periods is no longer apparent" (7, p.35).

Spooner and Kellogg (17) used 60 women students in an introductory psychology course as subjects. The CS was a buzz of 1000 cycles per sec. (cps) of 0.2-sec.

duration delivered at 55 decibels (db) above threshold at the ear. The UCS was a 0.2-sec. shock of sufficient voltage to give 6-inch finger movements. Criteria for a CR were withdrawal of right index finger, latency less than the interval between CS and UCS for group in question, latency within twice the interval between CS and UCS, and a 1.5-sec. interval applied to all groups. Each of six groups were assigned one of the following intervals: forward 1.5, 1.0, 0.5, simultaneous 0.0, and backward 0.5 and 0.25 secs. In this trace conditioning experiment "the validity of Wolfle's original findings is certainly corroborated by our own results. . . . The main contribution of this study is. . .the discovery that backward conditioning is apparently an entirely different phenomenon from forward conditioning. . . . The curve for backward and simultaneous conditioning. . .is more like the curve of extinction--or like the curve of forgetting" (17, pp.327-328).

There have been several studies of the temporal factors in conditioning the human eyeblink. Reynolds (13) used the click of a magnet in headphones as CS and the fall of 80 mm of mercury in a tube to produce a puff of air UCS. Two types of training--distributed and massed--were used in this trace conditioning experiment. Ss were 77 women students. Four forward time intervals between CS

and UCS were used--0.25, 0.45, 1.15 and 2.25 secs. Time between trials was 1-2 minutes for the distributed group and 1 minute for massed. "The results showed that the limits and rates of rise of the acquisition curves decrease for intervals shorter than or longer than 0.45 sec. [It is interesting to note that] the limits and rates of rise of the acquisition curves. . .were less than when acquisition trials were distributed" (13, p.30).

McAllister (10) investigated eyeblink conditioning using as the CS a 1000 cps tone, 50 db above the threshold of each S, and as the UCS, a puff of air, 1.6 pounds per square inch. CS-UCS intervals were 0.1, 0.25, 0.45, 0.7 and 2.5 secs. The CS and UCS terminated together. Forty-five Ss were assigned to the .45-sec. group and 15 to each of the others, with a 7 to 8 ratio of men to women for all groups. Anticipatory CRs and CRs present on certain unpaired test trials were counted. Results indicated that "the 0.25 sec. group reached a higher level of conditioning than did any other group. The longer the interval beyond 0.25 sec., the poorer was the performance. . . . It appears safe to conclude that eyelid conditioning under intervals as long as 2.5 sec. is poor or negligible" (10, p.420).

Conditioning of Autonomic Responses. Because a recent experiment by Moeller (11) parallels in some aspects the one to be reported here, it will be reviewed in some detail.

It was concerned with the gradient between the CS-UCS interval and level of conditioning of the trace-conditioned Féré GSR. A 0.10-sec. white noise CS was delivered to each S's headset at 20 db above his threshold. A condenser provided the 0.10-sec. shock to the tips of two fingers of the left hand. Shock intensity was adjusted by varying the voltage across the condenser. GSR contacts were to the palms. Because of subject boredom, they were required to give one free association to nouns presented once every 30 seconds. Training trials were interspersed between the presentation of the nouns.

Introductory psychology students were assigned in groups of 15 each to be given conditioning trials under one of five forward interstimulus intervals--0.25, 0.45, 1.0, 2.5 secs., and backward pseudo-conditioning control. On the first day the S's auditory threshold was determined by the method of limits in five presentations of the white noise. Shock was adjusted in three trials to unpleasant intensity. From then on, the voltage across the condenser was increased 10 volts (v.) every fourth ordinal trial.

"On the second day, three trials were devoted to readjustment of the shock, then S received eight adaptation trials, 23 conditioning trials, with seven test trials interspersed and five extinction trials. . . . The test trials were presented every second or third trial after

each increase in shock, with order of testing varied randomly from S to S" (11, p.163).

CRs were counted when there was a decrement of 200 ohms or more. Amplitude was measured in terms of conductance change. Each S's amplitudes were reduced by the mean on the last three adaptation trials.

"The function relating CS-UCS interval and performance in trace conditioning of the GSR was found to be very similar to that obtained in studies of eyelid and other responses involving skeletal musculature" (11, p.165). There was failure to find conditioning with the 2.5-sec. interval: "The performance of the 2.5-sec. group exemplified sensitization" (11, p.164).

These findings are consistent with those of White and Schlosberg (19) who investigated the impedance change GSR. In their experiment the CS was a light of 70.5 milliamberts intensity, 2.5 inches in diameter, presented four feet in front of and one foot above eye level. The UCS was a 150 v., 0.1 ma shock applied to the right wrist. The two stimuli terminated simultaneously after a 1.5-sec. overlap. There were 10 human subjects in each of the seven groups used. Time between onset of CS and UCS was 0.0 and 0.25, 0.5, 1, 2,and 4 secs. forward. There was also a group to control for pseudo-conditioning in which stimuli were unpaired. In the experimental groups, five pairings of

light and shock, then five of light alone, and finally five of shock alone were given. The same spacing held for the control group, but stimuli were not paired, and presentation of stimuli was random. Results were expressed in terms of per cent response on extinction trials.

> "The 0.5 sec. group is significantly superior to all other groups at well beyond the .01 level of confidence. . . . The original data were examined to see how many CRs in each delay-group actually exceeded the responses to S's terminal shock. Fourteen out of the 50 responses in the 0.5 sec. group satisfied this criterion, but only two to four did so in the other groups. Chi-square shows this difference to be far beyond the .01 level of confidence" (19, pp.358-359).

In the studies cited thus far, there has been a noticeable difficulty in obtaining conditioning with forward stimulus intervals of 2.5 secs. or longer. The following investigators have found conditioning with intervals of this length or longer.

Pavlov (12) found little difference in the effectiveness of CS-UCS intervals up to 5 secs. when CS continued until onset of UCS. Also, he often measured stimulus intervals in minutes instead of seconds and obtained evidence of delayed conditioning of the salivary response to an auditory stimulus CS and a UCS of food in the mouth for intervals up to several minutes.

Estes and Skinner (3), working with the concept of anxiety, which some relate to the functioning of the autonomic nervous system (9), gave 12 rats under high drive and 12 rats under low drive preliminary training. This consisted of paired tone-shock stimulation twice over six consecutive hourly periods after which tone was lengthened from three to five minutes and given once during each ensuing experimental hour. "The principal result of this part of the experiment was the conditioning of a state of anxiety to the tone, where the primary index was in reduction in strength of the hunger-motivated lever-pressing behavior" (3, p.392). Extinction results indicated the presence of conditioning: ". . .the tone was turned on after twenty-seven minutes of the experimental period had elapsed and allowed to sound for the remainder of the hour. . . . The recovery of a normal periodic rate is delayed considerably over the accustomed five minute period of tone" (3, pp. 396-397).

Rodnick (14) has performed an experiment comparing delay and trace conditioning of the human GSR. The CS was a faint patch of light at the level of the S's eye. The UCS was a shock to the right wrist sufficient to cause visible contraction of the arm muscle. The impedance change GSR was recorded by means of two dry silver electrodes strapped to the right palm a quarter inch apart. Some of the

university student Ss trained under delay conditions in which the shock of 0.625 sec. duration was given 20.1 secs. after onset of light. The latter extended 0.6 sec. beyond the shock. Five of the Ss were given trace conditioning in which the 0.18-sec. vibrator CS preceded the UCS by 17.4 secs. He concluded that "the course of the modification of the latency of the conditioned galvanic skin response was similar to that of delayed conditioned response, although the rate was much slower" (14, p.417). The important point here is that conditioning was found with the relatively long stimulus intervals which were used.

In a study by Steckle (18) GSR trace conditioning in adult human subjects was investigated. The CS was light from a 3.5 w. bulb three feet away on a level with the eyes. Its duration was 0.5 sec. The UCS was a strong shock to the pads of the index and middle fingers of the right hand. Twelve members of an experimental group were given 15 to 30 paired stimulations with 5.5 secs. between onsets of the light and shock. "In all cases a change in skin resistance. . . followed the shock. . . . When the reaction began to occur almost simultaneously with the administration of the shock, the test series was begun. Herein the light was presented alone. . . . Such a delay was found with six subjects. . . [that] a control group of six subjects was run. These subjects underwent a training series with shock alone over a

period similar to that of the experimental group. In the test series, the subjects were stimulated with light alone. A change in skin resistance occurred with all subjects except one who did not respond at all. For the remaining five subjects, 2.20 seconds was the average time between stimulation by the light and the occurrence of the response" (18, pp.477-479). The differences in latency were taken to indicate trace conditioning in the first group--i.e., the one in which a 5.0-sec. latency was used.

Summary of Empirical Findings

Backward conditioning is more difficult to accomplish than forward conditioning, as indicated by the findings pertaining to whole-body (1, 22), limited motor (2, 17, 20, 21), and autonomic responses (11). A basic difference may exist between backward and forward conditioning (17).

Simultaneous conditioning is relatively ineffective in the case of whole-body responses (1) and limited motor responses (20, 21), and may be so in the case of autonomic responses (19).

The optimal forward interval is in the 0.20-sec. to 1.0-sec. range for limited motor responses (7, 10, 13, 20, 21). This range may be similar for autonomic responses (11, 19). However, it has been suggested that there should be a different gradient for different classes of responses (7).

Theoretical Considerations

The experiments described above have been discussed in connection with the stimulus-response (S-R) versus stimulus-stimulus (S-S) controversy in learning. According to Spence (16) "this disagreement is whether the change conceived either as an associative link or an organized cognition, involves relating sensory and motor processes (S-R) or sets of sensory (perceptual) processes (S-S). . . . It is concerned entirely with the intrinsic, physiological properties of the hypothetical change" (16, p.243).

Although this is a question of considerable contemporary interest, the present experiment was not designed to contribute to its solution. This design is more critical for another type of problem which Moeller (11) has raised when he states that "in the present experiment the response was perhaps not conditioned directly, but a simple skeletal response, such as inspiration or tensing of the muscles, which results in a recorded GSR, was conditioned" (11, p.165). Therefore, "with the appropriate subsidiary assumptions, the prediction /would be/ that a measure of pure autonomic conditioning would yield a function which shifted upward /i.e., forward/ on the time axis" (11, p.165).

Previous studies using the Féré GSR have lacked suitable control of the contaminating factors in GSR measurement. A technique which results in improved control of these

variables is the impedance change GSR. This study is designed to measure more directly the temporal course of conditioning the GSR.

CHAPTER II

METHOD

Apparatus[1]

The 1000 cps pure tone CS, of 3 secs. duration, was generated by the commercially sold Grayson-Stadler Twin Oscillator, and was delivered to the headphones at 60 db above the 0.0002 dyne per square cm reference intensity. A 1 ma constant current UCS, which lasted 1 sec., was furnished by a specially constructed DC source. Two copper shock electrodes, 2 mm in diameter and 1 cm apart, made contact with the S's right index finger.

A specially constructed timer controlled the temporal aspects of the CS-UCS presentation. A Lafayette Multi-channel Recorder, No. 603 (which includes a galvanometer unit) continuously recorded the stimulus presentation and the GSR (see Plate I). The GSR electrodes were affixed to the index and third fingers of the left hand. A Ringer solution, zinc oxide electrode paste, described by Haggard (5), was applied to the GSR electrodes.

During the experiment proper, the S was isolated

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[1] See Appendices A, B, and C for a block diagram and circuit diagrams.

PLATE I

General View of the Apparatus.

from the E and from the apparatus by an opaque plastic curtain in one corner of a sound-shielded room (see Plate II). Because the switches were silent and the timer soundproofed, the apparatus was virtually noiseless in operation.

Subjects[1]

The Ss were 180 male volunteers, freshmen at the University of Florida, randomly selected and randomly assigned to one of the six experimental groups of 30 Ss each. Over 90% of those contacted took part, and none was dropped after his appearance at the laboratory.

Procedure

The time between the onset of the CS and the UCS was systematically varied from group to group according to the schedule diagrammed in Fig. 1. The groups were run during successive weeks.

Each S received a total of 20 trials in one sitting, with 45 secs. between the onsets of each trial. There was complete randomization of the presentation of shock for any given trial from S to S and group to group. Thus no S could foretell a shock or non-shock trial--even if he had conferred with an experienced S prior to his series of trials. A p of .50 was used.

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[1]See Appendix D for list of subjects.

PLATE II

Subject and Experimenter in Position at the Apparatus without the Screening Curtain in Place.

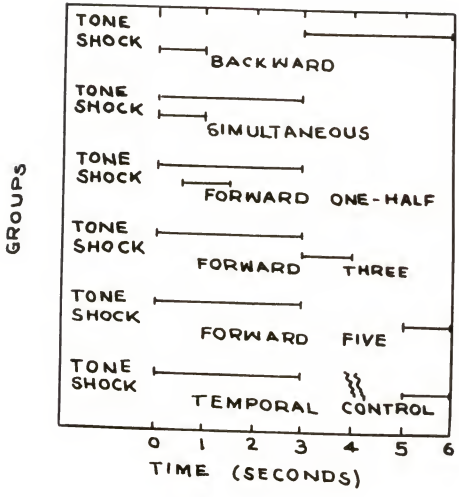


Fig. 1. Diagrammatic representation of the time interval between onset of CS and onset of UCS for the six experimental groups. The stimuli were presented individually to the Ss of the Temporal Control group.

Each S received the following instructions:

"Quickly touch the shock electrodes like this. As you see, the shock is not prohibitive. Next, I will place the shock electrodes on the index finger of your right hand, and a headset over your ears. Seat yourself as comfortably as possible. The curtain will be dropped and equipment adjusted just prior to the experiment proper. Please do not change your sitting position or relax completely until the curtain is raised. Questions will be answered afterwards."

Response Measures

Amplitude, latency, and recruitment measures were obtained on the CRs recorded for the last five non-shock trials. For these measures, CRs were counted when there was a change in skin resistance of 200 ohms or greater, and when the latency of these CRs was within the range 0.5 to 8.5 secs.

The frequency of CR was counted for the first and second half of the non-shock trials following the first shock trial. When there was an odd total of non-shock trials following the first shock trial, the middle trial was not counted as belonging to either half. The data for the halves were also combined to give the total group frequency data. Frequency of response for trials prior to

the first shock trial was counted as well.

Amplitude was measured by use of the formula $\log_{10}\left(R\frac{1}{\text{basic}} - R\frac{1}{\text{maximum}}\right) + 10$ (i.e., $\log_{10}$ conductance change plus the constant 10 which eliminates negative scores), in keeping with the findings of Haggard (4). Other measures were: latency--the time in seconds from onset of the CS to the first drop in the skin resistance; recruitment--the time in seconds from the first drop in skin resistance to the first maximum in the skin resistance drop; frequency--in terms of a skin resistance drop equal to (a) 10% or (b) 5% of the basic skin resistance just prior to the drop (provided that this drop occurred in the 0.5 to 8.5 sec. interval after onset of the CS).

CHAPTER III

RESULTS

The mean CR amplitude and recruitment data are presented in Figs. 2 and 3. Mean CR latencies, in secs., for the last five non-shock trials were as follows for the temporal, backward, simultaneous, and forward one-, three-, and five-second conditioning groups, respectively: 2.0, 1.9, 2.0, 2.0, 1.9, and 2.2.

Data from analysis of variance are presented in Table I for amplitude and Table II for recruitment. The F ratio for Time Interval against Subjects is 4.1 for the amplitude and 5.7 for the recruitment data, respectively. The F ratio for Time Interval against Subjects is 3.2 for the amplitude and 3.6 for the recruitment data, respectively. These Fs are significant at the .01 level.

Tests for homogeneity of variance for data pertaining to non-shock trials following the first shock trial were made by Bartlett's method as described by Lindquist (8). By inspection, the chi square for CR amplitude data was not significant even at the .10 level. Chi square for CR recruitment data was 83.6, significant at the .001 level, thus indicating heterogeneity. The same test of homogeneity

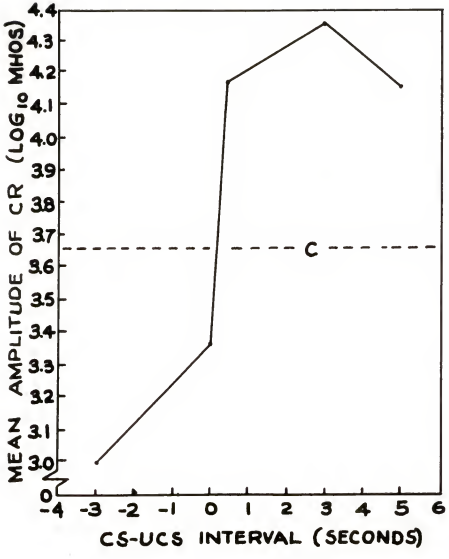


Fig. 2. Mean amplitude of CR for last five non-shock trials in terms of log conductance change in mhos plotted as a function of the time in seconds between the onsets of the CS and the UCS. For the Temporal Control group (C) the time between onsets was 45 secs.

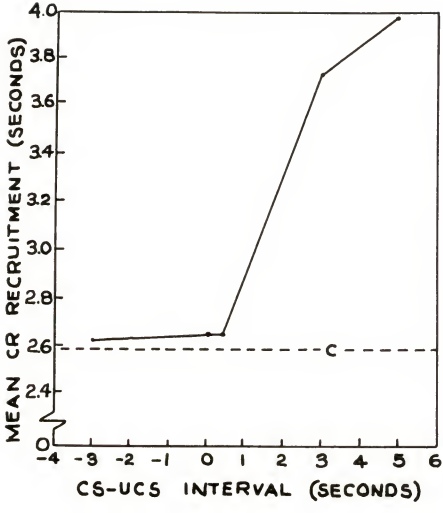


Fig. 3. Mean recruitment of CR in seconds plotted as a function of the time in seconds between the onsets of the CS and UCS for the last five non-shock trials. For the Temporal Control group (C) the time between onsets was 45 secs.

TABLE I
Summary of Analysis of Variance Data
for Amplitude of CR
Last Five Non-shock Trials

	df	ss	ms	F	P
Time Interval	5	219.32	43.86	4.1	.01
Subjects	29	309.24	10.66	3.2	.001
(Cells)	(179)	(1671.08)			
Interaction	145	1142.52	7.88		
Within-Cells (w)	720	2382.18	3.30		
Total	899	4053.26			

TABLE II
Summary of Analysis of Variance Data
for Recruitment of CR
Last Five Non-shock Trials

	df	ss	ms	F	P
Time Interval	5	220.53	44.10	5.7	.001
Subjects	29	222.93	7.68	3.6	.001
(Cells)	(179)	(1512.95)			
Interaction	145	1069.49	7.38		
Within-Cells (w)	720	1526.15	2.12		
Total	899	3039.10			

applied to the amplitude and recruitment data for the last five non-shock trials yielded chi squares of 19.0 and 78.2, significant at the .01 and .001 levels, respectively.

The frequency data expressed as percentages of CR are presented in Figs. 4 and 5. The two levels of control group data (C) in these graphs may be attributed to the fact that more responses to tone alone occurred in the first half of the non-shock trials as compared with the second half of such trials. Chi squares for the total group CR frequencies (i.e., those obtained by combining the data for the two halves for each group) were 152.4 and 155.0 for the 10% and 5% criterial levels, respectively. Both are significant at the .001 level.

Response percentages for the non-shock trials preceding the first shock trials are presented in Fig. 6. The data for trials 1, 2, 3, and 4 are based on 85, 53, 20, and 4 non-shock trials, respectively.

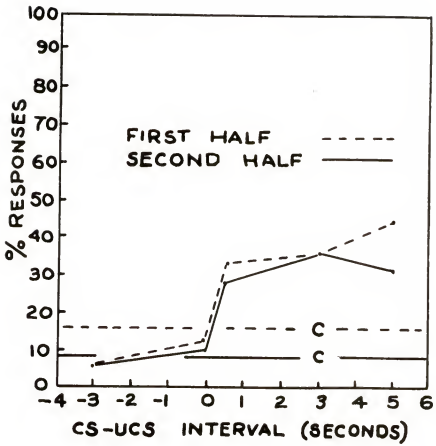


Fig. 4. Frequency of CR expressed as the percentage of response and plotted as a function of the CS-UCS time interval for the first and second half of the shock trials following the first shock trial. A CR was counted when the response equaled or was greater than 10% of the basic skin resistance just prior to the elicitation of the CR. C indicates Temporal Control group.

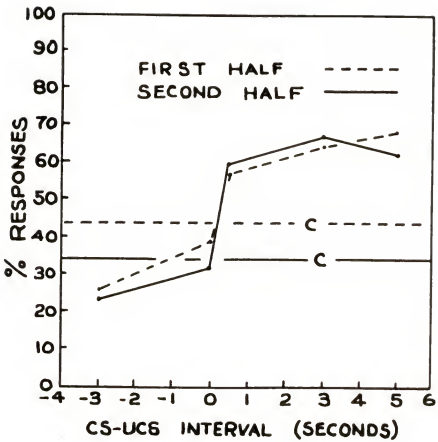


Fig. 5. Frequency of CR expressed as the percentage of response and plotted as a function of the CS-UCS time interval for the first and second half of the shock trials following the first shock trial. A CR was counted when the response equaled or was greater than 5% of the basic skin resistance just prior to the elicitation of the CR. C indicates Temporal Control group.

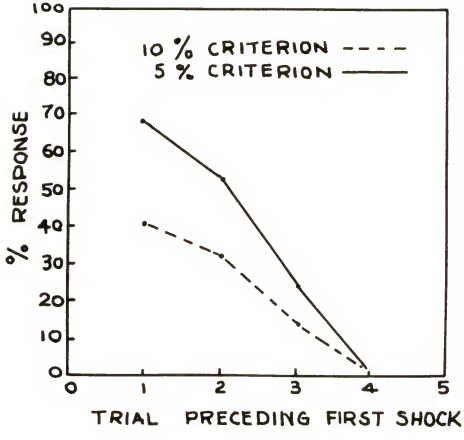


Fig. 6. Frequency of GSR during auditory stimulation prior to shock trials plotted for successive trials. A response was counted when the criterion was (a) 10% and (b) 5% of the basic skin resistance just prior to its elicitation.

CHAPTER IV

DISCUSSION

The most important finding of this experiment is that the temporal gradient relating CS-UCS interval to level of classical conditioning of the impedance change GSR in human subjects is shifted upward on the time axis--that is, to the longer intervals--and approaches zero amplitude more slowly, as compared with phasic responses. Hence, by inspection of the mean amplitude (Fig. 2) and frequency (Figs. 4 and 5) data, the optimal interval appears to be in the vicinity of 3.0 secs. and not in the 0.2-1.00 sec. range found to be most efficacious for skeletal responses (7, 10, 13, 20, 21). Furthermore, it appears that conditioning occurred when the forward 5.0-sec. interval was used.

The significance of the data presented in Figs. 2, 4, and 5 is enhanced by the regularity in form of each of the curves and the similarities between them. These factors indicate a progressive increase in the amount of conditioning as one moves from the backward to the forward three-second conditioning groups. There is also an inflection point at three seconds for the amplitude and for

the frequency data for the last half of the non-shock trials. Moreover, the F ratio for the amplitude and the chi square for the frequency data indicate that the time interval is an effective variable. The data for the more sensitive 5% criterial level (as indicated by the greater magnitude of the control group percentages) parallel that of the 10%.

The heterogeneity of variance in the amplitude data for the last five non-shock trials may or may not be of importance since, according to Lindquist (8), "the Bartlett test will not indicate how marked the heterogeneity really is, nor how severely it affects the validity of the usual F-test" (8, p.88). The lack of heterogeneity in the amplitude data for non-shock trials following the first shock trial suggests that the GSR amplitude measure, as recommended by Haggard (4), was not responsible for the heterogeneity found in the data for the last five non-shock trials.

The main findings are not readily explained by Brown's interpretation (originally proffered in reference to the results of Moeller (11) regarding the Fêré GSR) to the effect that "a skeletal response mediates the recorded GSR" (11, p.165). If so, it would appear that the findings would have been similar to those in studies made with regard to optimal CS-UCS interval (7, 10, 13, 20, 21), and conditioning when the CS-UCS interval is 2.5 secs. or more (10, 17, 20, 21). They were not. Thus, a relatively pure

measure of the GSR may have been accomplished in this experiment. This would be in keeping with the interpretation Moeller (11) made of his data to the effect that "with appropriate subsidiary assumptions a measure of pure autonomic conditioning would yield a function which was shifted upward on the time axis" (11, p.165).

The question arises: Why are the findings of this experiment not in accord with those of White and Schlosberg (19) who also investigated the impedance change GSR? Since they used but 10 Ss in each group, five pairings of the CS and UCS, and one response measure and found no significant differences except for the 0.5-sec. group, their results may not be reliable.

Backward conditioning is less effective than forward as indicated by the amplitude and frequency data in Figs. 2, 4, and 5. These data may indicate that the Ss were actively learning not to give a response to the tone (since one already existed as indicated later in this discussion.) This interpretation would be in keeping with that of Spooner and Kellogg (17) to the effect that backward conditioning is a different process from forward conditioning. In any event, the backward conditioning group, sometimes used as a control group (11), may provide a less sensitive control than one in which the stimuli were never paired.

The recruitment data (Fig. 3) indicate that re-

cruitment time was influenced more by the CS-UCS interval as such than by the amplitude of the response. The recruitment mean for the 0.5-sec. group is quite low, and that for the 5.0-sec. group highest, although they have comparable amplitude means. The significant Bartlett test (8) of homogeneity is also indicative of the correlation between CS-UCS interval and magnitude of recruitment means.

In view of the recruitment data, it is surprising that the latency means, which differed little and showed no trend, were not influenced by CS-UCS interval as such. Both measures may be rather insensitive measures of conditioning.

The frequency data (Figs. 4 and 5), for the first half of the non-shock trials following the first shock trial, indicate that conditioning was rapid. The data pertaining to frequency of response prior to the first shock trial (Fig. 6) provide a clue. Since the frequency of response was relatively high for the first few trials prior to the first shock, the conditioning trials may have sustained, heightened, or diminished an existent response to tone by itself in the case of Ss who were shocked on the first, second, or third trials.

The data in Fig. 6 do suggest that adaptation to tone was rapid, thus indicating that the presence of shock on certain trials was an active factor in the presence of CR on the later trials.

CHAPTER V

SUMMARY AND CONCLUSIONS

This experiment investigated the temporal gradient in the classical conditioning of the impedance change GSR for human Ss, using partial reinforcement.

There were six groups--one control (CS-tone and UCS-shock unpaired) and five experimental (trained at CS-UCS intervals of -3.0, 0.0, 0.5, 3.0 and 5.0 secs. each.) Thirty randomly selected freshmen males at the University of Florida served in each group. Twenty trials were given in one sitting, with 45 secs. between trials. The UCS was presented in random order from trial to trial. Amplitude, latency, and recruitment data were analysed for the last five non-shock trials. Frequency data were analysed for virtually all of the non-shock trials.

Conclusions

(a) There is a temporal gradient which has a maximum at the 3.0 sec. interval.

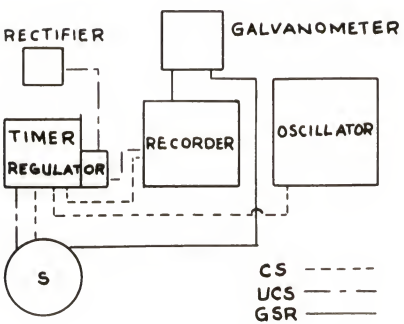
(b) The impedance method of representing GSR is consistent with the physiological approach to the GSR, and

a temporal gradient may be established with this method.

(c) This study has not lent support to either the S-S or S-R position as a description of conditioning.

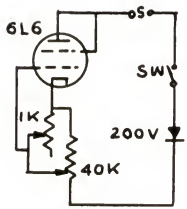
APPENDIX A

BLOCK DIAGRAM OF APPARATUS



APPENDIX B

DIAGRAM OF SHOCK CIRCUIT

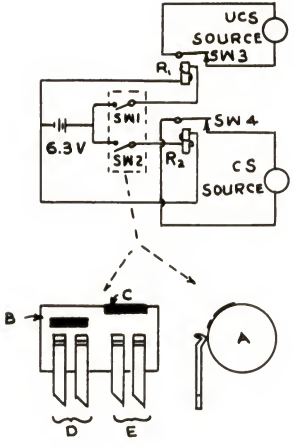


DESCRIPTION OF SHOCK CIRCUIT DIAGRAM (APPENDIX B)

This circuit supplies a constant current; thus the voltage applied to the S is proportional to his apparent resistance. The cathode bias method of controlling the current flow through the 6L6 Beam Power Amplifier tube makes possible such regulation. The 40,000-ohm wirewound control potentiometer is used to vary the amount of current to that desired up to approximately 5 ma. The 1,000-ohm adjustable resistor prevents an excessive current flow when the potentiometer resistance drops to zero or near zero. The resistor should never be adjusted to a value of less than 500 ohms. The 200 v. DC source is supplied by a full-wave rectifier. (The maximum current supplied by this circuit may be increased by increasing the voltage of this source.) The switch may be controlled manually or automatically, depending on the type of switch desired.

APPENDIX C

DIAGRAM OF TIMER CIRCUIT



DESCRIPTION OF TIMER CIRCUIT DIAGRAM (APPENDIX C)

A synchronous motor driven drum (A) closed Switch 1 and Switch 2 according to a schedule determined by the velocity of rotation of the drum and the width and relative placement of metal strips B and C. Because of their constant pressure against the drum, the contacts of Pair D and Pair E were closed when the strips rotated into proper position. Closure of Switch 1 activated Relay 1, closing Switch 3, completing the UCS shock circuit. When Switch 2 was closed, Relay 2 was activated, completing the CS tone circuit.

APPENDIX D

LIST OF NAMES OF THOSE WHO VOLUNTEERED

TO SERVE AS SUBJECTS

Adkinson, Harvey E.
Allen, Albert Wilson
Armstrong, Russell F.
Aucamp, David H., Jr.
Barfield, James Ervin
Barnes, Charles Henry
Bean, Robert Roy
Beard, Harold Franklin
Bearman, Alfred Saul
Becker, John Bryan
Bennett, Robert Earl
Benson, William R., Jr.
Bergin, Padraic A.
Blewitt, John Clifford
Blumberg, Howard L.
Bolin, Robert David
Boling, Dardon Nabar
Bowden, James William
Bowen, Donald Clyde
Bowling, Gerald Lee
Brame, Charles Lowell
Brown, Alan Steven
Brown, Fred David
Brown, Raymond Deen
Burion, Garrett Oliver
Burwell, Harry S.
Butler, Lee C.
Cameron, Clifford Ray
Campos, Joe P., Jr.
Canales, Gover P.
Cannon, Reisman
Carlton, Cecil Curtis
Carter, Johnie J.
Champa, Marion Bernard
Clark, Kay Orville
Claudy, Robert
Coffman, Clarence W., Jr.
Constantinides, P. B.
Cureton, David D., Jr.
Daleo, George

Debarry, James Grady
Debats, Charles Martin
Demar, Joseph Duane
Dewey, Ray Harold
Dixon, Richard Black
Doerr, Clarence Cody
Duerk, Eugene Myron
Dykes, Lewis Eugene
Eaddy, Morris Lee
Eaker, Charles Lemuel
Eaker, Howard Keith
Earnest, Robert L. III
Easterling, Alford G.
Engstrom, George
Ellis, Jack R.
Etherton, Donald M.
Ewing, Terrence C.
Faulk, John Wesley
Faulkner, Joe Franklin
Fewell, Gilbert O.
Fitzgerald, Louie F.
Fletcher, James Robert
Foster, James Robert
Fuentes, Joe
Gallagher, Neil Peter
Giffen, John Clark
Glass, Robert
Goudy, Raymond L.
Grafft, Robert Wm.
Graves, James Ray
Green, Alan C.
Greer, Joseph Leon
Gregory, Roy William
Haff, Milton Charles
Hankins, Billy Charles
Hassell, Jerry Eugene
Henry, Edward Franklin
Herring, Arbie Grad, Jr.
Hettinger, Vann Earl
Hinkley, David Thomas
Huggins, Harvey B., Jr.
Hughes, James Thomas
Hulme, Colin Clive
Humphreys, David W.
Hurst, Norman Oliver
Ivey, Robert Dorsey, Jr.
Johnson, Shelby Allen
Jones, Donald Adam
Jones, Leo Wilson
Jones, Wyman Lloyd

Keen, William Merdic
Kimber, Ronald Winston
Knight, Peter Stanley
Koske, Johnny Roman
Krantz, Robert Lee
Lake, Hugh
Langford, Accum Parker
Lankow, George Henry
Lasseter, Lee Thomas
Lee, David T.
Lewis, Donald Joseph
Leybourne, James J.
Lide, Thomas Edwin
Lim, Richard Keiwong
Maddox, L. Vern, Jr.
Mankowitz, Harold, Jr.
Marlowe, Curtiss A.
Masters, James Irwin
McCormick, Charles E.
McCullough, Joe Thomas
McKee, Kenneth
McKee, Louis Hyatt
McMillan, Joseph C.
McMullen, Harvey A.
McWilliams, Clayton, Jr.
Meginley, Dan Steel
Melton, Robert Dennis
Meyer, Richard Albert
Milam, William Earl
Miller, Charles Robt.
Millergren, Nils A.
Moll, William
Morrill, Charles A.
Oberholtzer, Robert E.
Ott, Rudolph Richard
Outterson, John Albert
Owen, Robert Shepherd
Paul, Charles Eugene
Pent, Raymond Temple
Percy, John Ellsworth
Peterson, Donald Lee
Peterson, Thomas Louis
Pierce, George Hinton
Pierce, Robert Michael
Pitts, Fred
Pritchard, Harry S., Jr.
Randall, Norman L., Jr.
Reams, James Neil
Redfearn, William H., Jr.
Rees, David Whitney

Riddell, Robert M., Jr.
Robb, Donald Hersie
Roughton, Ernest W., Jr.
Routh, Joseph O., Jr.
Rudderman, Philip T.
Rutter, Paul Samuel
Saigh, Victor Andrew
Sapp, Kenneth Norris
Sawyer, Robert Webb
Schoen, John Robert
Schulz, Gerald Owen
Seale, Peter Gordon
Shaffer, Clyde Hoover
Shanks, Ferrell Bates
Sheffield, Charles Wm.
Smith, Donald Lee
Sowry, Oliver Duane
Sparkman, William E.
Staats, Robert Bryant
Stack, Charles Rickman
Steinovitz, Gideon
Stewart, Norman Lee
Stewart, Thomas
Stone, Ronald A.
Storer, William Happer
Sutton, James Robert
Swan, Jack Weaver
Thomas, Robert Lowell
Tuttle, Richard B.
Tyree, Bennie Earl
Tyus, Howard Kenneth
Wakeland, Robert Arlen
Watson, Clayton Lee
Weekes, King David
Whidden, Myrle A.
Wilson, John Oliver
Wilt, Robert Eugene
Wingfield, John Dyson
Wolfenbarger, Dan
Wootin, Edwin

BIBLIOGRAPHY

1. Carr, H. A., and Freeman, A. S. Time relationships in the formation of association. Psychol. Rev., 1919, 26, 465-473.

2. Coppock, H. W. Stimuli preceding electric shock can acquire positive reinforcing properties. J. comp. physiol. Psychol., 1954, 47, 109-113.

3. Estes, W. K., and Skinner, B. F. Some quantitative properties of anxiety. J. exp. Psychol., 1941, 29, 390-400.

4. Haggard, E. A. On the application of analysis of variance to GSR data: I. The selection of an appropriate measure. J. exp. Psychol., 1949, 39, 378-392.

5. Haggard, E. A. On the application of analysis of variance to GSR data: II. Some effects of the use of inappropriate measures. J. exp. Psychol., 1949, 39, 861-867.

6. Hilgard, E. R. Methods and procedures in the study of learning. In S. S. Stevens (Ed.), Handbook of experimental psychology. New York: John Wiley, 1951. Pp. 517-567.

7. Kappauf, W. E., and Schlosberg, H. Conditional responses in the white rat: III. Conditioning as a function of the length of the period of delay. J. genet. Psychol., 1937, 50, 27-45.

8. Lindquist, E. F. Design and analysis of experiments in psychology and education. Boston: Houghton Mifflin, 1953.

9. Lindsley, D. B. Emotion. In S. S. Stevens (Ed.), Handbook of experimental psychology. New York: John Wiley, 1951. Pp. 473-516.

10. McAllister, W. R. Eyelid conditioning as a function of the CS-UCS interval. J. exp. Psychol., 1953, 45, 417-422.

11. Moeller, G. The CS-UCS interval in GSR conditioning. J. exp. Psychol., 1954, 48, 162-166.

12. Pavlov, I. P. Conditioned reflexes. (trans. G. V. Anrys.) London: Oxford Univ. Press, 1927.

13. Reynolds, B. The acquisition of a trace conditioned response as a function of the magnitude of the stimulus trace. J. exp. Psychol., 1945, 35, 15-30.

14. Rodnick, E. H. Characteristics of delayed and trace conditioned responses. J. exp. Psychol., 1937, 20, 409-425.

15. Schlosberg, H. A study of the conditioned patellar reflex. J. exp. Psychol., 1928, 11, 468-494.

16. Spence, K. W. Theoretical interpretations of learning. In C. P. Stone (Ed.), Comparative psychology. New York: Prentice-Hall, 1951. Pp. 239-291.

17. Spooner, A., and Kellogg, W. N. The backward conditioning curve. Amer. J. Psychol., 1947, 60, 321-344.

18. Steckle, L. C. A trace conditioning of the galvanic reflex. J. gen. Psychol., 1933, 9, 475-480.

19. White, C. T., and Schlosberg, H. Degree of conditioning of the G. S. R. as a function of the period of delay. J. exp. Psychol., 1952, 43, 357-362.

20. Wolfle, H. M. Time factors in conditioning finger-withdrawal. J. gen. Psychol., 1930, 4, 372-378.

21. Wolfle, H. M. Conditioning as a function of the interval between the conditioned and the original stimulus. J. gen. Psychol., 1932, 7, 80-103.

22. Yarborough, J. U. The influence of the time interval upon the rate of learning in the white rat. Psychol. Monogr., 1921, 30, no. 135.

BIOGRAPHICAL SKETCH

William Baylor Bierbaum was born in Louisville, Kentucky, March 16, 1924. He attended elementary and secondary schools in Louisville, and the University of Louisville. After serving in the Armed Forces, he graduated from the University of Florida with the degree of Bachelor of Science, with Honors, in June, 1949, and received his Master of Arts degree in February, 1951, from the same institution. His graduate work has been in the fields of Psychology and Sociology. He is at present a school psychologist in the Pinellas County, Florida, schools, a member of the summer and night faculty at St. Petersburg Junior College, Associate-at-Large in the Florida Psychological Association, immediate past secretary of the Tampa Bay Psychological Association, and an associate member of the American Psychological Association, the Southeastern Psychological Association, and the Southern Society for Philosophy and Psychology. He is married and has a daughter and a son.

This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of the committee. It was submitted to the Dean of the College of Arts and Sciences and to the Graduate Council and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

June 6, 1955

E. T. Byers
Dean, College of Arts and Sciences

Dean, Graduate School

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